FULL COLOR LED BASED LIGHTING APPARATUS OPERATED IN SYNCHRONISM WITH MUSIC AND METHOD OF CONTROLLING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to lighting system and more particularly to a full color LED (light-emitting diode) based lighting apparatus operated in synchronism with music and method of controlling the same with improved characteristics.

2. Description of Related Art

A conventional LED lighting system can be installed in a large square, billboard, or any of other appropriate places (e.g., restaurants, large meeting places, pubs, concerts, or the like). Lighting is typically controlled by a lighting engineer who, in often times, cannot provide lighting in synchronism with music. Thus, a desired lighting in synchronism with sound cannot be obtained.

Thus, it is desirable to provide an LED based lighting apparatus operated in synchronism with music capable of operate in synchronism with music in a live event for providing more excitement, fun, and entertainment.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a full color LED based lighting apparatus operated in synchronism with music and method of controlling the same. By utilizing the present invention, a plurality of advantages are obtained as detailed below.

In a first preferred embodiment, LED color can be controlled by different audio frequencies for carrying out a single loop frequency control full color LED

based lighting apparatus operated in synchronism with music.

In a second preferred embodiment, an audio frequency is divided into a high frequency band and a low frequency band in which one frequency band is adapted to control background color of LEDs and the other one is adapted to control foreground color of LEDs for carrying out a double loop frequency control full color LED based lighting apparatus operated in synchronism with music.

In a third preferred embodiment, an audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively so as to carry out a triple loop frequency control full color LED based lighting apparatus operated in synchronism with music.

In a fourth preferred embodiment, LED color is controlled by changing a loop frequency and LED brightness is controlled by changing a loop amplitude for carrying out a single loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

In a fifth preferred embodiment, an audio frequency is divided into a high frequency band and a low frequency band in which one frequency band is adapted to control background color of LEDs, the other one is adapted to control foreground color of LEDs, and a whole LED brightness is controlled by a loop amplitude for carrying out a double loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

In a sixth preferred embodiment, an audio frequency is divided into a high frequency band and a low frequency band in which one frequency band is adapted to control background color of LEDs, the other one is adapted to control foreground color of LEDs, and loop brightness is controlled by a loop

amplitude for carrying out a double loop frequency and double loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

In a seventh preferred embodiment, an audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively, and a whole LED brightness is controlled by loop amplitude so as to carry out a triple loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

In an eighth preferred embodiment, an audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively, and loop brightness is controlled by loop amplitude for carrying out a triple loop frequency and triple loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description taken with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a first preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 2 is a block diagram of a second preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 3 is a block diagram of a third preferred embodiment of LED based

lighting apparatus operated in synchronism with music according to the invention;

FIG. 4 is a block diagram of a fourth preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 5 is a block diagram of a fifth preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 6 is a block diagram of a sixth preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 7 is a block diagram of a seventh preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 8 is a block diagram of an eighth preferred embodiment of LED based lighting apparatus operated in synchronism with music according to the invention;

FIG. 9 is a flow chart illustrating a first process according to the invention;

FIG. 10 is a flow chart illustrating a subroutine of the first process illustrated in FIG. 9;

FIG. 11 is a flow chart illustrating a second process according to the invention; and

FIGS. 12 to 19 are flow charts illustrating first to eighth subroutines of the second process illustrated in FIG. 11.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown an LED based lighting apparatus

operated in synchronism with music constructed in accordance with a first preferred embodiment of the invention. The apparatus comprises an audio frequency band-pass filter 10, a level comparator 20, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the level comparator 20. The level comparator 20 is adapted to further amplify the sound signals and convert amplified signals having a voltage higher than a reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The microcontroller 40 comprises a CPU (central processing unit), a RAM (random access memory), and a ROM (read only memory) having a firmware for controlling the CPU. The integration circuit 30 is adapted to process the square-wave signals fed from the level comparator 20 for obtaining a corresponding frequency which is in turn stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process input/output (I/O) and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling LED color. This forms a single loop frequency control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 2, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a second preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band and a low frequency band in which one of the frequency bands is adapted to control background color of LEDs and the other one is adapted to control foreground color of LEDs.

Alternatively, one of the frequency bands is adapted to control foreground color of LEDs and the other one is adapted to control background color of LEDs. The apparatus comprises an audio frequency band-pass filter 10, a high frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the high frequency band-pass amplification circuit 21 and the low frequency band-pass amplification circuit 22 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass amplification circuit 22 comprises a second level comparator 220. The high frequency band-pass amplification circuit 21 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to

process the square-wave signals fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling background color of LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling foreground color of LEDs. This forms a double loop frequency control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 3, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a third preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively. The apparatus comprises an audio frequency band-pass filter 10, a high frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, an intermediate frequency band-pass amplification circuit 23, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio

frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the high frequency band-pass amplification circuit 21, the low frequency band-pass amplification circuit 22, and the intermediate frequency band-pass amplification circuit 23 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass amplification circuit 22 comprises a second level comparator 220. The low frequency band-pass amplification circuit 22 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The intermediate frequency band-pass amplification circuit 23 comprises a third level comparator 230. The intermediate frequency band-pass amplification circuit 23 and the third level comparator 230 together form a third detection loop of intermediate frequency band. The third detection loop of intermediate frequency band is adapted to further amplify signals having an intermediate frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted

to process the square-wave signals fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling blue LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling red LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the third level comparator 230 for obtaining a corresponding frequency in response to input from the third detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling green LEDs. This forms a triple loop frequency control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 4, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a fourth preferred embodiment of the invention. The apparatus is characterized in that LED color is controlled by changing loop frequency and LED brightness is controlled by changing loop amplitude. The apparatus comprises an audio frequency band-pass filter 10, a first amplitude detection circuit 24, a band-pass

amplification circuit 25, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the first amplitude detection circuit 24 and the band-pass amplification circuit 25 respectively. The first amplitude detection circuit 24 comprises an ADC (analog-to-digital converter) 240. The first amplitude detection circuit 24 and the ADC 240 together form an amplitude detection loop. The amplitude detection loop is adapted to obtain peaks of signals and convert the peaks of signals into digital amplitudes of signals by means of the ADC 240 prior to inputting to the integration circuit 30 for reading. The band-pass amplification circuit 25 comprises a fourth level comparator 250. The band-pass amplification circuit 25 and the fourth level comparator 250 together form a frequency detection loop. The frequency detection loop is adapted to further amplify signals and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to store the amplitudes of signals in a register in response to input from the ADC 240. The CPU is adapted to read out the amplitudes of signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling LED brightness. The integration circuit 30 is adapted to store the square-wave signals in the register in response to input from the fourth level comparator 250. The CPU is adapted to read out the square-wave signals from the register. Also, the integration

circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling LED color. This forms a single loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 5, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a fifth preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band and a low frequency band in which one of the frequency bands is adapted to control background color of LEDs and the other one is adapted to control foreground color of LEDs. Alternatively, one of the frequency bands is adapted to control foreground color of LEDs and the other one is adapted to control background color of LEDs. Further, a whole LED brightness is controlled by loop amplitude. The apparatus comprises an audio frequency band-pass filter 10, a high frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, a first amplitude detection circuit 24, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the high frequency band-pass amplification circuit 21, the low frequency band-pass amplification circuit 22, and the first amplitude detection circuit 24 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and

convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass amplification circuit 22 comprises a second level comparator 220. The low frequency band-pass amplification circuit 22 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The first amplitude detection circuit 24 comprises an ADC 240. The first amplitude detection circuit 24 and the ADC 240 together form an amplitude detection loop. The amplitude detection loop is adapted to obtain peaks of signals and convert the peaks of signals into digital amplitudes of signals by means of the ADC 240 prior to inputting to the integration circuit 30 for reading. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to process the square-wave signals fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling background color of LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is

adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling foreground color of LEDs. The integration circuit 30 is further adapted to store the amplitudes of signals in the register in response to input from the ADC 240. The CPU is adapted to read out the amplitudes of signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling a whole LED brightness. This forms a double loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 6, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a sixth preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band and a low frequency band in which one of the frequency bands is adapted to control background color of LEDs and the other one is adapted to control foreground color of LEDs. Alternatively, one of the frequency bands is adapted to control foreground color of LEDs and the other one is adapted to control background color of LEDd. Further, loop brightness is controlled by loop amplitude. The apparatus comprises an audio frequency band-pass filter 10, a high frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, a second amplitude detection circuit 26, a third amplitude detection circuit 27, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to

inputting to the high frequency band-pass amplification circuit 21 and the low frequency band-pass amplification circuit 22 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass amplification circuit 22 comprises a second level comparator 220. The low frequency band-pass amplification circuit 22 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The second amplitude detection circuit 26 comprises an ADC 260. The second amplitude detection circuit 26 and the ADC 260 together form a detection loop of high frequency amplitude. The detection loop of high frequency amplitude is adapted to obtain peaks of signals having a high frequency and convert the peaks of signals into digital high frequency amplitudes of signals by means of the ADC 260 prior to inputting to the integration circuit 30 for reading. The third amplitude detection circuit 27 comprises an ADC 270. The third amplitude detection circuit 27 and the ADC 270 together form a detection loop of low frequency amplitude. The detection loop of low frequency amplitude is adapted to obtain peaks of signals having a low frequency and convert the peaks of signals into digital low frequency amplitudes of signals by means of the ADC

270 prior to inputting to the integration circuit 30 for reading. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to process the square-wave signals fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling background color of LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling foreground color of LEDs. The integration circuit 30 is further adapted to store the high frequency amplitudes in the register in response to input from the ADC 260. The CPU is adapted to read out the high frequency amplitudes from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling brightness of the first detection loop. The integration circuit 30 is further adapted to store the low frequency amplitudes in the register in response to input from the ADC 270. The CPU is adapted to read out the low frequency amplitudes from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling brightness of the second detection loop. This forms a double loop frequency

and double loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 7, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with a seventh preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively. Further, a whole LED brightness is controlled by loop amplitude. The apparatus comprises an audio frequency band-pass filter 10, a high frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, an intermediate frequency band-pass amplification circuit 23, a first amplitude detection circuit 24, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the high frequency band-pass amplification circuit 21, the low frequency band-pass amplification circuit 22, and the intermediate frequency band-pass amplification circuit 23 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass

amplification circuit 22 comprises a second level comparator 220. The low frequency band-pass amplification circuit 22 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The intermediate frequency band-pass amplification circuit 23 comprises a third level comparator 230. The intermediate frequency band-pass amplification circuit 23 and the third level comparator 230 together form a third detection loop of intermediate frequency band. The second detection loop of intermediate frequency band is adapted to further amplify signals having an intermediate frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The first amplitude detection circuit 24 comprises an ADC 240. The first amplitude detection circuit 24 and the ADC 240 together form an amplitude detection loop. The amplitude detection loop is adapted to obtain peaks of signals and convert the peaks of signals into digital amplitudes of signals by means of the ADC 240 prior to inputting to the integration circuit 30 for reading. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to process the square-wave signals fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling blue LEDs. The

integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling red LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the third level comparator 230 for obtaining a corresponding frequency in response to input from the third detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling green LEDs. The integration circuit 30 is adapted to store the amplitudes of signals in the register in response to input from the ADC 240. The CPU is adapted to read out the amplitudes of signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling a whole LED brightness. This forms a triple loop frequency and single loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

Referring to FIG. 8, there is shown an LED based lighting apparatus operated in synchronism with music constructed in accordance with an eighth preferred embodiment of the invention. The apparatus is characterized in that audio frequency is divided into a high frequency band, an intermediate frequency band, and a low frequency band for controlling blue, red, and green color LEDs respectively. Further, loop brightness is controlled by loop amplitude. The apparatus comprises an audio frequency band-pass filter 10, a high

frequency band-pass amplification circuit 21, a low frequency band-pass amplification circuit 22, an intermediate frequency band-pass amplification circuit 23, a second amplitude detection circuit 26, a third amplitude detection circuit 27, a fourth amplitude detection circuit 28, an integration circuit 30, a microcontroller 40, and an LED drive circuit 50. Each component will be described in detail below.

The audio frequency band-pass filter 10 is adapted to filter out signals other than sound source in sound input for obtaining sound signals. Also, the audio frequency band-pass filter 10 is adapted to amplify the sound signals prior to inputting to the high frequency band-pass amplification circuit 21, the low frequency band-pass amplification circuit 22, and the intermediate frequency band-pass amplification circuit 23 respectively. The high frequency band-pass amplification circuit 21 comprises a first level comparator 210. The high frequency band-pass amplification circuit 21 and the first level comparator 210 together form a first detection loop of high frequency band. The first detection loop of high frequency band is adapted to further amplify signals having a high frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The low frequency band-pass amplification circuit 22 comprises a second level comparator 220. The low frequency band-pass amplification circuit 22 and the second level comparator 220 together form a second detection loop of low frequency band. The second detection loop of low frequency band is adapted to further amplify signals having a low frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The intermediate frequency band-pass amplification circuit 23 comprises a third level comparator 230. The

intermediate frequency band-pass amplification circuit 23 and the third level comparator 230 together form a third detection loop of intermediate frequency band. The third detection loop of intermediate frequency band is adapted to further amplify signals having an intermediate frequency band and convert the amplified signals having a voltage higher than the reference voltage into square-wave signals prior to inputting to the integration circuit 30 for frequency calculation. The second amplitude detection circuit 26 comprises an ADC 260. The second amplitude detection circuit 26 and the ADC 260 together form a detection loop of high frequency amplitude. The detection loop of high frequency amplitude is adapted to obtain peaks of signals having a high frequency and convert the peaks of signals into digital high frequency amplitudes of signals by means of the ADC 260 prior to inputting to the integration circuit 30 for reading. The third amplitude detection circuit 27 comprises an ADC 270. The third amplitude detection circuit 27 and the ADC 270 together form a detection loop of low frequency amplitude. The detection loop of low frequency amplitude is adapted to obtain peaks of signals having a low frequency and convert the peaks of signals into digital low frequency amplitudes of signals by means of the ADC 270 prior to inputting to the integration circuit 30 for reading. The fourth amplitude detection circuit 28 comprises an ADC 280. The fourth amplitude detection circuit 28 and the ADC 280 together form a detection loop of intermediate frequency amplitude. The detection loop of intermediate frequency amplitude is adapted to obtain peaks of signals having an intermediate frequency and convert the peaks of signals into digital intermediate frequency amplitudes of signals by means of the ADC 280 prior to inputting to the integration circuit 30 for reading. The microcontroller 40 comprises a CPU, a RAM, and a ROM having a firmware for controlling the CPU. The integration circuit 30 is adapted to process the square-wave signals

fed from the first level comparator 210 for obtaining a corresponding frequency in response to input from the first detection loop. The corresponding frequency is stored in a register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling blue LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the second level comparator 220 for obtaining a corresponding frequency in response to input from the second detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling red LEDs. The integration circuit 30 is also adapted to process the square-wave signals fed from the third level comparator 230 for obtaining a corresponding frequency in response to input from the third detection loop. The corresponding frequency is stored in the register. The CPU is adapted to read out the frequency from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling green LEDs. The integration circuit 30 is adapted to store the high frequency amplitudes of signals in the register in response to input from the ADC 260. The CPU is adapted to read out the high frequency amplitudes of signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling brightness of the first detection loop. The integration circuit 30 is adapted to store the low frequency amplitudes of signals in the register in response to input from the ADC 270. The CPU is adapted to read out the low frequency amplitudes of

signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling brightness of the second detection loop. The integration circuit 30 is adapted to store the intermediate frequency amplitudes of signals in the register in response to input from the ADC 280. The CPU is adapted to read out the intermediate frequency amplitudes of signals fed from the register. Also, the integration circuit 30 is adapted to process I/O and scan signals sent from the CPU, and send the processed signals to the LED drive circuit 50 for controlling brightness of the third detection loop. This forms a triple loop frequency and triple loop amplitude control full color LED based lighting apparatus operated in synchronism with music.

It is noted that in the second and fifth preferred embodiments, frequency obtained by the first detection loop is also adapted to control foreground color of LEDs and frequency obtained by the second detection loop is also adapted to control background color of LEDs. Alternatively, frequency obtained by the first detection loop is adapted to control background color of LEDs and frequency obtained by the second detection loop is adapted to control foreground color of LED. It is further noted that in the third, seventh, and eighth preferred embodiments, frequencies obtained by the first, second, and third detection loops are adapted to control blue, red, and green LEDs respectively, blue, green, and red LEDs respectively, red, blue, and green LEDs respectively, red, green, and blue LEDs respectively, green, blue, and red LEDs respectively, or green, red, and blue LEDs respectively.

Referring to FIG. 9, there is shown a first process according to the invention. Steps of the first process will now be described in detail below. First, initialize the register and I/O values, clear SRAM (static RAM), and set

parameters (step 1). Next, read out display function of parameters setting value from an input port (step 3). Finally, call a subroutine (e.g., interrupt subroutine) as detailed below (step 6).

The flow chart of FIG. 10 illustrates a call subroutine of the first process. In step 5, output signal to the integration circuit 30 in response to data in a scan buffer of SRAM. The subroutine returns to the first process immediately.

The flow chart of FIG. 11 illustrates a second process according to the invention. Steps of the second process will now be described in detail below. First, initialize the register and I/O values, clear SRAM, and set parameters (step 1). Next, read out a machine type parameter (step 2). Next, read out display function of parameters setting value from the input port (step 3). Next, determine the machine type from the read machine type parameter (step 4). Finally, call one of subroutines 61, 62, 63, 64, 65, 66, 67, and 68 based on the machine type as detailed below.

The flow chart of FIG. 12 illustrates the subroutine 61 of the second process with respect to the single loop frequency control. First, read out frequency from the integration circuit 30 (step 71). Next, select a corresponding LED color based on the frequency (step 81). Finally, display based on the display function parameters (step 91) prior to returning to the second process.

The flow chart of FIG. 13 illustrates the subroutine 62 of the second process with respect to the double loop frequency control. First, read out frequencies of high frequency loop and low frequency loop from the integration circuit 30 (step 72). Next, select a corresponding background color of LEDs based on the frequency of high frequency loop and select a corresponding foreground color of LEDs based on the frequency of low frequency loop (step 82). Finally, display based on the display function parameters (step 92) prior to returning to the second process.

The flow chart of FIG. 14 illustrates the subroutine 63 of the second process with respect to the triple loop frequency control. First, read out frequencies of high frequency loop, intermediate frequency loop, and low frequency loop from the integration circuit 30 (step 73). Next, select a corresponding blue LED based on the frequency of high frequency loop, select a corresponding red LED based on the frequency of low frequency loop, and select a corresponding green LED based on the frequency of intermediate frequency loop (step 83). Finally, display based on the display function parameters (step 93) prior to returning to the second process.

The flow chart of FIG. 15 illustrates the subroutine 64 of the second process with respect to the single loop frequency and single loop amplitude control. First, read out frequency of frequency loop and amplitude of amplitude loop from the integration circuit 30 (step 74). Next, select a corresponding LED color based on the frequency and adjust LED brightness based on amplitude of the amplitude loop (step 84). Finally, display based on the display function parameters (step 94) prior to returning to the second process.

The flow chart of FIG. 16 illustrates the subroutine 65 of the second process with respect to the double loop frequency and single loop amplitude control. First, read out frequencies of high frequency loop and low frequency loop and amplitude of the amplitude loop from the integration circuit 30 (step 75). Next, select a corresponding background color of LEDs based on the frequency of high frequency loop, select a corresponding foreground color of LEDs based on the frequency of low frequency loop, and adjust LED brightness based on amplitude of the amplitude loop (step 85). Finally, display based on the display function parameters (step 95) prior to returning to the second process.

The flow chart of FIG. 17 illustrates the subroutine 66 of the second process with respect to the double loop frequency and double loop amplitude

control. First, read out frequencies of high frequency loop and low frequency loop and amplitudes of high frequency amplitude loop and low frequency amplitude loop respectively (step 76). Next, select a corresponding background color of LEDs based on the frequency of high frequency loop, select a corresponding foreground color of LEDs based on the frequency of low frequency loop, adjust background brightness of the LED based on frequency of the high frequency amplitude, and adjust foreground brightness of the LED based on frequency of the low frequency amplitude (step 86). Finally, display based on the display function parameters (step 96) prior to returning to the second process.

The flow chart of FIG. 18 illustrates the subroutine 67 of the second process with respect to the triple loop frequency and single loop amplitude control. First, read out frequencies of high frequency loop, intermediate frequency loop, and low frequency loop, and amplitude of the amplitude loop from the integration circuit 30 (step 77). Next, select a corresponding red LED based on the frequency of low frequency loop, select a corresponding green LED based on the frequency of intermediate frequency loop, select a corresponding blue LED based on the frequency of high frequency loop, and adjust brightness of the LED based on amplitude of the amplitude loop (step 87). Finally, display based on the display function parameters (step 97) prior to returning to the second process.

The flow chart of FIG. 19 illustrates the subroutine 68 of the second process with respect to the triple loop frequency and triple loop amplitude control. First, read out frequencies of high frequency loop, intermediate frequency loop, and low frequency loop, and amplitudes of high frequency amplitude loop, intermediate frequency amplitude loop, and low frequency amplitude loop from the integration circuit 30 (step 78). Next, select a

corresponding red LED based on the frequency of low frequency loop, select a corresponding green LED based on the frequency of intermediate frequency loop, select a corresponding blue LED based on the frequency of high frequency loop, adjust brightness of the red LED based on low frequency amplitude, adjust brightness of the green LED based on intermediate frequency amplitude, and adjust brightness of the blue LED based on high frequency amplitude (step 88). Finally, display based on the display function parameters (step 98) prior to returning to the second process.

Note that the color selection methods of the invention can be different based on different sound control techniques. Fortunately, a lookup table can be employed for shortening operation time. In detail, a color conversion table comprising a single color conversion table and a full color conversion table can be created in advance based on operating results. These conversion tables are shown as follows:

single color conversion table

	Frequency range (Hz)	Value (hex)		Frequency range (Hz)	Value (hex)		Frequency range (Hz)	Value (hex)
R	20-29	7F	G	300-329	FF	B	5000-5059	3F
	30-39	77		330-359	F7		5060-5119	4F
	40-49	6F		360-389	EF		5120-5179	5F
	50-59	67		390-419	E7		5180-5239	6F
	60-69	5F		420-449	DF		5240-5299	7F
	...			...			...	
	180-199	BF		4700-4749	2F		19400-19499	AF
	200-219	AF		4750-4799	37		19500-19599	9F
	220-239	9F		4800-4849	3F		19600-19699	8F
	240-259	8F		4850-4899	47		19700-19799	7F

	260-279	7F		4900-4949	4F		19800-19899	6F
	280-299	6F		4950-4999	57		19900-19999	5F

full color conversion table

Frequency range(Hz)	R、G、B values (3 bytes hex)
20-29	FF,0,7F
30-39	FF,3F,7F
40-49	FF,7F,7F
50-59	FF,BF,7F
60-69	FF,FF,7F
. . .	. . .
4700-4749	FF,0,FF
4750-4799	BF,0,FF
4800-4849	7F,0,FF
4850-4899	3F,0,FF
4900-4949	3F,3F,FF
4950-4999	3F,7F,FF

Note that the single color conversion table is applicable to the triple loop frequency control implemented in the third embodiment.

Further note that frequency band is chosen at a range from 20Hz to 20kHz with a bandwidth of 19.98kHz when the frequency scale technique of the invention, for example, in the embodiment of single loop frequency control is carried out. As to conversion of frequency into color table, a conversion table having a memory of 19,980 x 3B= 59,940B is required in which each color in the order of R(red), G(green), and B(blue) is represented by 3B. Larger memory space is required for any of other embodiments (control techniques) as detailed below.

A. Full frequency range equal division: Each frequency scale is 20Hz with 999 (19,980/20=999) scales in which a first color table corresponds to 20Hz to

39Hz, a second color table corresponds to 40Hz to 59Hz, a third color table corresponds to 60Hz to 79Hz, ..., and a 999th color table corresponds to 19,980Hz to 19,999Hz.

B. Full frequency range equal section division: The full frequency range is divided into a plurality of equal sections each being further divided into a plurality of equal scales in which the total number of scales is 303 (10+12+15+20+40+50+60+80+76=303). It only requires less than one third of the color table and has a better scale effect as compared to the full range equal division. An exemplary table is as follows:

Frequency band serial number	Frequency range	Frequency width /scale	Number of scale
1	20-119Hz	10Hz	10
2	120-299Hz	15Hz	12
3	300-599Hz	20Hz	15
4	600-1199Hz	30Hz	20
5	1200-2999Hz	40Hz	40
6	3000-5999Hz	60Hz	50
7	6000-12399Hz	80Hz	80
8	12400-19999Hz	100Hz	76

C. Full frequency range sine function calculation scale division (sin(0) to sin(90)): Bandwidth (bw) is 19,980Hz. Number of scales is s. Frequency is f. Let f0=f-19, corresponding color table (tb)

$$tb = s \times \sin[(f0/bw) \times 90]$$

$$= s \times \sin(f0/222)$$

Choose an integral part of tb based on unconditional carry rule. For example, tb=300 sin(f0/222) if the number of scales (s) is 300. Tb is at a range of 1 $\leqq$ tb $\leqq$ 300 after choosing the integral part of tb.

Still further note that brightness adjustment by means of amplitude of the invention is detailed in the following example. Color values of R, G, and B are FF, 3F, and 7F (hex) after frequency conversion. Amplitude is 90 (hex). Amplitude ratio is 90/FF. Converted color values of R, G, and B after multiplying the amplitude ratio are as follows:

$$R = FF \times 90/FF = 90$$

$$G = 3F \times 90/FF = 23$$

$$B = 7F \times 90/FF = 47$$

In brief, the invention is directed to a full color LED based lighting apparatus operated in synchronism with music and method of controlling the same based on the sound source so as to provide lighting in synchronism with music. In short, LED color and LED brightness can be controlled by means of high and low frequencies of sound. Thus, lighting can be controlled so as to be in synchronism with music as an event proceeds. Hence, sound is excellent. Also, tenderness in one time and high spirit in the other time can be carried out as the event proceeds. Further, it is lively and shocking.

While the invention herein disclosed has been described by means of specific embodiments, numerous modifications and variations could be made thereto by those skilled in the art without departing from the scope and spirit of the invention set forth in the claims.